

(19) World Intellectual Property Organization
International Bureau



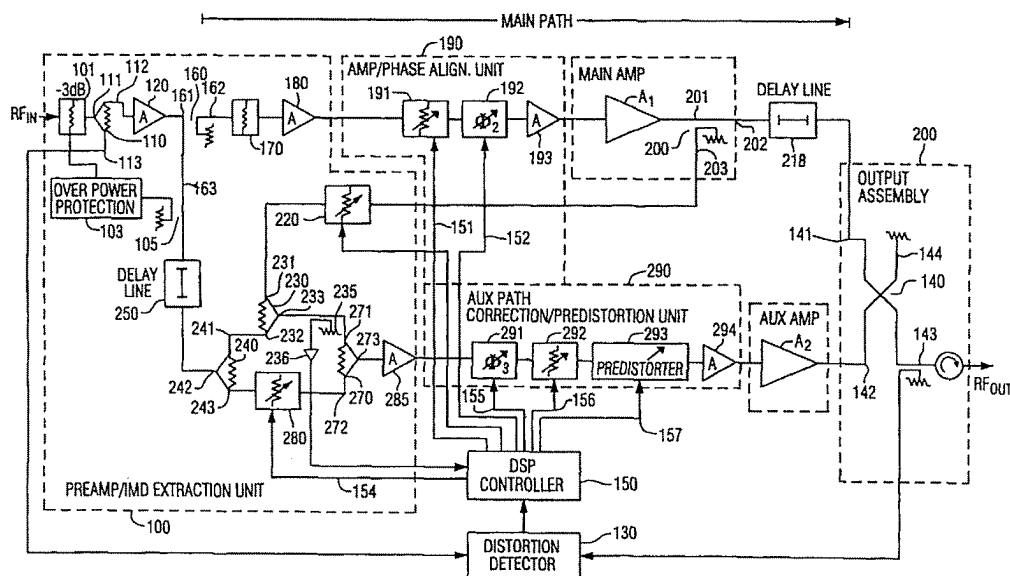
(43) International Publication Date
25 January 2001 (25.01.2001)

PCT

(10) International Publication Number
WO 01/06640 A1

- (51) International Patent Classification⁷: **H03F 1/26**, 1/00, H04K 1/02
- (21) International Application Number: PCT/US00/19365
- (22) International Filing Date: 14 July 2000 (14.07.2000)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
09/356,166 16 July 1999 (16.07.1999) US
- (71) Applicant: **SPECTRIAN CORPORATION** [US/US];
350 West Java, Sunnyvale, CA 94089 (US).
- (72) Inventors: **COVA, Armando, C.**; 1063 Morse Avenue,
Apartment #4-201, Sunnyvale, CA 94089 (US). **MUCE-
NIEKS, Lance, T.**; 200 Riverview Drive, Boulder Creek,
CA 95006 (US).
- (74) Agent: **WANDS, Charles, E.**; Law Offices of Charles E.
Wands, Suite 211, 5240 Babcock Street, N.E., Palm Bay,
FL 32905 (US).
- (81) Designated States (*national*): CA, JP, KR.
- (84) Designated States (*regional*): European patent (AT, BE,
CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC,
NL, PT, SE).
- Published:**
— With international search report.
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: HIGH EFFICIENCY FEED-FORWARD RF POWER AMPLIFIER WITH PREDISTORTION ENHANCEMENT



(57) Abstract: An RF power amplifier linearization architecture contains main and auxiliary path RF amplifiers. A distortion-inverting circuit (100) extracts the distortion component from the output signal of the main amplifier (A1) and combines it with a delayed sample of the RF input signal to drive an auxiliary path RF amplifier (A2), via a predistorter (293). An output quadrature hybrid (200) combines the output of the main and auxiliary path amplifiers. The cascading of the distortion-inverting circuit with the predistorter compensates for the non-linear behavior of the auxiliary path RF power amplifier (A2) thereby producing a composite signal at the output quadrature hybrid (200), in which RF carrier components from each amplifier combine constructively while distortion components cancel.

WO 01/06640 A1

HIGH EFFICIENCY FEED-FORWARD RF POWER
AMPLIFIER WITH PREDISTORTION ENHANCEMENT

5 CROSS-REFERENCE TO RELATED APPLICATION

10 The present application is a continuation-in-part of
co-pending U.S. Patent application Serial No. 09/195,536,
filed November 18, 1998, by L. Mucenieks et al, entitled:
"RF Power Amplifier Linearization Using Parallel RF Power
Amplifiers Having Intermod-Complementing Predistortion
Paths," (hereinafter referred to as the '536 application),
assigned to the assignee of the present application and the
disclosure of which is incorporated herein.

15 FIELD OF THE INVENTION

20 The present invention relates in general to
communication systems, and is particularly directed to an
RF power amplifier linearization mechanism, that employs
digital signal processor-controlled pre- and post-
distortion circuitry in the respective input and output
paths of a main RF power amplifier, and predistortion
circuitry installed in the input path of an auxiliary, feed-
forward RF power amplifier, to which the input and output
of the main RF amplifier are coupled, and the output of
which is combined with that of the main RF power amplifier,
25 to produce a composite amplified signal with substantially
reduced intermodulation products.

30 BACKGROUND OF THE INVENTION

35 As described in the above-referenced '536 application,
communication service providers are subject to very strict
bandwidth usage spectrum constraints, including technically
mandated specifications and regulations imposed by the
Federal Communications Commission (FCC). These rules
require that sideband spillage, namely the amount of energy
spillover outside a licensed band of interest, be sharply
attenuated (e.g., on the order of 50 dB). Although these
regulations may be easily met for traditional forms of
modulation, such as FM, they are difficult to achieve using

more contemporary, digitally based modulation formats, such as M-ary modulation.

5 Attenuating the sidebands sufficiently to meet industry or regulatory-based requirements by means of such modulation techniques requires very linear signal processing systems and components. Although relatively linear components can be implemented at a reasonable cost at relatively narrow bandwidths (baseband) of telephone networks, linearizing components such as power amplifiers
10 at RF frequencies can be prohibitively expensive.

A fundamental difficulty in linearizing RF power amplifiers is the fact that they are inherently non-linear devices, and generate unwanted intermodulation distortion products (IMDs) that manifest themselves as spurious
15 signals in the amplified RF output signal, such as spectral regrowth or spreading of a compact spectrum into spectral regions that do not appear in the RF input signal. This distortion causes the phase/amplitude of the amplified output signal to depart from the phase/amplitude of the
20 input signal, and may be considered as an incidental (and undesired) amplifier-sourced modulation of the RF input signal.

An inefficient approach to linearizing an RF power amplifier is to build the amplifier as a large, high power device, and then operate the amplifier at a low power level
25 (namely, at only a small percentage of its rated output power), where the RF amplifier's transfer characteristic is relatively linear. An obvious drawback to this approach is the overkill penalty - a costly and large sized RF device.

30 Other prior art techniques include baseband polar (or Cartesian) feedback, post-amplification, feed-forward correction, and pre-amplification, pre-distortion correction. In the first approach, the output of the amplifier is compared to the input and a baseband error signal is used to directly modulate the signal which enters
35 the power amplifier. In the second approach, error (distortion) present in the RF amplifier's output signal is

extracted, amplified to the proper level, and then reinjected (as a complement of the error signal back) into the output path of the amplifier, so that (ideally) the RF amplifier's distortion is effectively canceled.

5 In the third approach, a predistortion signal is injected into the RF input signal path upstream of the RF amplifier. The predistortion signal ideally has a characteristic that is equal and opposite to the distortion expected at the output of the high power RF amplifier, so
10 that when subjected to the (distorting) transfer characteristic of the RF amplifier, it effectively cancels the output distortion. Predistortion may be made adaptive by measuring the distortion at the output of the RF amplifier and adjusting the predistortion control signal to
15 minimize the distortion of the output signal of the power amplifier during real time operation.

In accordance with the invention described in the above-referenced '536 application and diagrammatically illustrated in Figure 1, linearization of a main RF power
20 amplifier A_1 is effectively achieved by using a second RF amplifier A_2 , that is largely matched with the main RF power amplifier A_1 . Being matched implies that the two RF amplifiers have the same transfer characteristics - both in terms of their intended RF performance and unwanted IMD
25 components they inherently introduce into their amplified outputs.

An RF input signal to be amplified is split by a directional coupler CPL1 into two paths, a first of which adjusts the RF input signal in amplitude and phase prior to
30 being amplified by the amplifier A_1 . A second split RF input signal path is used to construct a signal consisting of both of the original RF input signal to be amplified by the second amplifier A_2 , and a complementary version of the IMD products the two amplifiers inherently introduce.

35 By selectively combining the RF output of the RF power amplifier A_1 with the RF input signal in the parallel path, the gain and phase adjusted RF input signal applied to the

matched amplifier A_2 can be made to include the same modulated RF carrier component as that applied to power amplifier A_1 . In addition, the adjusted RF input signal to the parallel path matched amplifier A_2 will contain a complementary version of the intermodulation component of the output of the main path amplifier A_1 .

The gain and phase adjustment of the input to the second amplifier A_2 is such that its RF output signal will have the desired RF carrier modulation component aligned with that of the main path amplifier A_1 , but its undesired intermod component will be of equal amplitude and phase-reversed with respect to the undesired intermod component of the RF output of the main path amplifier A_1 . Combining these two matched amplifier outputs in a quadrature hybrid CPL2 yields a composite signal, in which the desired amplified modulated RF carrier components produced by each matched amplifier constructively sum to the intended amplification level, while unwanted IMD components destructively combine or cancel, effectively leaving only the desired amplified modulated RF carrier.

SUMMARY OF THE INVENTION

In accordance with the present invention, advantage may be taken of a work function-based predistortion mechanism, to enhance the operation of the auxiliary path predistortion mechanism described in the '536 application. Pursuant to a preferred embodiment, the predistortion mechanism for the signal path of the auxiliary RF amplifier may be derived from respectively different work functions of the instantaneous amplitude of the RF input signal. As a non-limiting example, the work function-based predistortion mechanism may be of the type described in U.S. Patent No. 5,760,646 (or '646 patent), by D. Belcher et al, entitled: "Feed-Forward Correction Loop with Adaptive Predistortion Injection for Linearization of RF Power Amplifier," issued June 2, 1998, assigned to the assignee of the present application and the disclosure of which is herein incorporated. This predistortion unit

5 serves to improve the match of the non-linear transfer characteristic between the first and second amplifiers and to reduce the additional distortion from the second amplifier, which arises from the presence of a distortion component at the input of the second amplifier, which does not exist at the input of the first amplifier.

10 As an addition to the linearization scheme of the above-referenced '536 application, the output of the carrier-IMD combiner is coupled to an auxiliary path-installed, processor-controlled predistortion unit that includes a processor-controlled phase shifter, a variable attenuator, and work function-based predistorter. These phase and amplitude parameters are controlled by digital signal processing circuitry, so that part of the IMD
15 distortion is canceled within the auxiliary amplifier, and the remaining portion is canceled by the main path distortion summed in the output quadrature hybrid.

20 As an adjunct to phase and amplitude adjustments, the predistorter of the auxiliary path is used to further distort the input signal to the second amplifier. This may be accomplished with work function predistortion control signals generated in the manner described in the above-referenced '646 patent, being derived from respectively different work functions of the instantaneous amplitude of
25 the RF input signal. The portion of the complementary distortion signal incident on the second amplifier, which is used to cancel the distortion energy of the main amplifier in the output quadrature hybrid is consequently predistorted to negate the non-linear effects of the second
30 amplifier on this distortion component. In addition to reducing the distortion arising from this complementary distortion signal at the output of the second amplifier, the predistorter can also serve to provide a better match between the non-linear transfer characteristics of the main
35 (first) and error (second) amplifiers.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 diagrammatically illustrates an RF power

amplifier linearization mechanism described in the above-referenced '536 application; and

Figure 2 diagrammatically illustrates a preferred embodiment of the present invention.

DETAILED DESCRIPTION

Before describing in detail the new and improved high efficiency feed-forward RF power amplifier linearization mechanism in accordance with the present invention, it should be observed that the invention resides primarily in a prescribed arrangement of conventional RF communication circuits, associated digital signal processing components and attendant supervisory control circuitry, that controls the operation of such circuits and components. As a result, the configuration of such circuits components and the manner in which they interface with other communication system equipment have, for the most part, been illustrated in the drawings by readily understandable block diagrams, which show only those details that are pertinent to the present invention, so as not to obscure the disclosure with details which will be readily apparent to those skilled in the art having the benefit of the description herein.

Thus, the block diagram illustrations are primarily intended to show the major components of an RF amplifier distortion correction system in a convenient functional grouping, whereby the present invention may be more readily understood. In addition, to facilitate an understanding of signal processing flow through the respective paths of the linearization system of the embodiments of the invention, reduced complexity spectral diagrams of the desired modulated RF carrier and the unwanted IMD components have been placed throughout the Figures in association with respective transfer characteristics of the system components.

Figure 2 diagrammatically illustrates a non-limiting example of an RF power amplifier linearization scheme in accordance with the present invention. As shown therein, an RF input signal RF_{in} to be amplified by a main RF amplifier

5 A_1 is coupled to a pre-amplification IMD extraction unit 100, that includes (-3dB) attenuation pad 101 to an input 111 of a power divider, shown as a Wilkinson splitter 110. Attenuation pad 101 is coupled to an over-power protection circuit 103, that is ported to a directional coupler 105 installed in a split signal output path of an input buffer amplifier 120.

10 A first output port 112 of Wilkinson splitter 110 is coupled to input buffer amplifier 120, while a second output port 113 is coupled to a first input 131 of a distortion detector 130. Distortion detector 130 is operative to monitor the input RF signal, and the output port 143 of an additive cancellation quadrature hybrid 140 within an output assembly 200. In response thereto, the
15 distortion detector 130 supplies a DSP-based controller 150 with a measure of any distortion energy in the composite RF output signal derived by combining the output of the main path RF power amplifier A_1 and the output of an auxiliary feed-forward RF power amplifier A_2 , that is largely matched
20 with RF power amplifier A_1 .

25 The DSP-based controller 150 executes one or more error minimization algorithms for controlling variable attenuators and phase shifters in both main amplifier and auxiliary amplifier signal paths, to effect cancellation of IMD components at the output port 143 of quadrature hybrid 140. It also computes control signals for the predistortion unit. As described in the '646 patent, the predistortion signals can be derived from respectively different work functions of the instantaneous amplitude of the RF input
30 signal extracted by Wilkinson splitter 110, that are used to predistort phase and amplitude components of the RF input signal to the auxiliary RF amplifier A_2 .

35 The output of the buffer amplifier 120 is coupled to an input port 161 of a directional coupler 160. Directional coupler 160 has a first output port 162 coupled to a main amplifier signal path that includes a preset attenuator pad 170 and a buffer amplifier 180, the output of which is

coupled through a main amplifier amplitude/phase alignment unit 190 to the main RF amplifier A_1 . The main path predistortion unit 190 includes a vector modulator comprised of a processor-controlled variable attenuator 191 and phase shifter 192, that are coupled in cascaded with a buffer amplifier 193. The main path vector modulator's attenuator 191 and phase shifter 192 controllably adjust the amplitude and phase of the RF input signal applied to the main RF amplifier A_1 , in accordance with respective amplitude and phase control signals supplied over links 151 and 152 from DSP controller 150.

The RF input signal produced by the main path amplitude/phase alignment unit 190 is supplied to the main path RF power amplifier A_1 , the output of which is coupled to an input port 201 of a directional coupler 200. Directional coupler 200 has a first output port 202 coupled through a delay line 218 to a first input port 141 of additive cancellation quadrature hybrid 140. Quadrature hybrid 140 has a second input port 142 coupled to receive the amplified output of auxiliary feed-forward RF power amplifier A_2 , and produces a composite amplified RF output signal at output port 143.

Delay line 250 is employed to equalize propagation delay through the main signal path and a processor-controlled variable attenuator 220, coupled between a second output port 203 of directional coupler 200 and a first input port 231 of a carrier cancellation combiner 230 (which may be configured as a Wilkinson combiner, as shown). The variable attenuator 220 controllably imparts a prescribed amount of attenuation to the second split path portion of the amplified RF output of the main path RF amplifier A_1 , in accordance with an attenuation control signal supplied over link 153 from DSP controller 150, and serves to set the gain of the main path when the digital control loops (which drive gain and phase adjusters 191 and 192) are closed.

As described above, RF carrier cancellation combiner

230 is used to extract the IMD portion of the output of the RF amplifier A_1 , by subtracting the split RF output signal from the main RF amplifier A_1 from the split RF signal in the auxiliary feed-forward path derived from the second port 163 of directional coupler 160. For this purpose, a second input port 232 of the carrier cancellation combiner 230 is coupled to a first output port 241 of a Wilkinson splitter 240, the input port 242 of which is coupled via a delay line 250 to second output port 163 of the directional coupler 160. The delay line 250 serves to equalize the propagation delay of the RF input signal from the second output port 163 of the directional coupler 160 for ensuring proper phase alignment of the signals applied to input ports 231 and 232 of carrier cancellation combiner 230.

Selectively combining the extracted distortion from the main path RF power amplifier A_1 with the split RF input signal produces an RF input signal with distortion products inverted with respect to the carriers, when compared to those in the main path amplifier A_1 . This signal is then fed via gain amplifier 285 to the correction/predistortion unit 290. The resulting input signal that is coupled to the correction/predistortion unit includes the same modulated RF carrier input component applied to the main path amplifier A_1 , and a complementary version of the intermodulation component of the output of the main path amplifier A_1 .

The complementary intermod component of the desired composite RF input signal to the auxiliary amplifier A_2 is obtained by coupling the output port 233 of the RF carrier cancellation combiner 230 to a first input port 271 of a carrier-IMD combiner 270. Via a directional coupler 235, the output port 233 of the RF carrier cancellation combiner 230 is coupled to a power detector 236, the output of which is monitored by DSP controller 150 and used to control variable attenuator 191 and variable phase shifter 192, so as to minimize the signal level at the output port 233 of carrier cancellation combiner 230.

5 The RF input component of the composite RF input signal to the auxiliary feed-forward amplifier A_2 is obtained by coupling a second output port 243 of the Wilkinson splitter 240 through a controlled variable
10 attenuator 280 to a second input port 272 of carrier-IMD combiner 270. Variable attenuator 280 is controlled by a control line 154 from DSP controller 150 to insert a controlled amount of attenuation into the path of the input RF signal extracted by directional coupler 160, which effectively sets the carrier/IMD ratio at the output of carrier/IMD combiner 270.

15 The output 273 of the carrier-IMD combiner 270 is coupled via buffer amplifier 285 to correction/predistortion unit 290. The predistortion unit 290 includes a processor-controlled vector modulator comprised of a phase shifter 291, and a variable attenuator 292. It also includes a predistorter 293. These three processor-controlled components are driven by respective control signals applied over lines 155, 156, and 157 from DSP
20 controller 150, and are coupled in cascade through a buffer amplifier 294 to auxiliary RF amplifier A_2 .

25 As in the main path amplitude/phase alignment unit 190, variable phase shifter 291 and attenuator 292 are operative to adjust the phase and amplitude of the RF signal supplied via predistorter 293 to the auxiliary RF amplifier A_2 , in accordance with respective phase and amplitude control signals from DSP controller 150, and thereby introduce prescribed amounts of phase shift and attenuation to the carrier/inverted IMD signal input to the
30 auxiliary feed-forward RF amplifier A_2 . As described in the above-referenced '536 application, these phase and amplitude parameters are controlled, so that part of the IMD distortion is canceled within the RF amplifier A_2 , and the remaining portion is canceled by the main path distortion summed in the quadrature hybrid 140.

35 As an adjunct to the respective phase and amplitude adjustments controllably imparted by phase shifter 291 and

attenuator 292, the predistorter 293 is used to further distort the RF input signal to the auxiliary RF amplifier A_2 , in accordance with predistortion control signals on line 157 from DSP processor 150. These auxiliary predistortion control signals may be generated in the manner described in the above-referenced '646 patent, and are used to control the phase and amplitude of different work functions of the instantaneous amplitude of the RF input signal from Wilkinson splitter 110.

As a consequence, predistortion unit 290 is also operative to correct for the distortion by the auxiliary amplifier A_2 of the complementary distortion energy that is fed forward through the auxiliary amplifier A_2 to the output quadrature hybrid 140 and correct for the difference in the distortion generated by the main amplifier A_1 and the auxiliary amplifier A_2 , which arises from the presence of a complementary distortion signal at the input of the auxiliary amplifier, which does not exist at the input of the main path amplifier. As detailed in the '646 patent, the predistorter 293 may utilize a pair of gain and phase adjustment circuits, such as a fast variable attenuator and a fast phase shifter, respectively, coupled in cascade in the signal path to the input of auxiliary RF amplifier A_2 .

In this predistorter, each work function signal is controllably weighted in a weighting coefficient multiplier unit, by respective amplitude and phase component-associated weighting coefficients generated by a weighting coefficient generator, in accordance with error measurements conducted on the signal at the output port 143 of quadrature hybrid 140. The error measurements may be carried out in the time domain, as by way of a coherent receiver comparing the amplifier input and output signals, to derive respective amplitude and phase error signals.

Alternatively, the error measurements may be carried out in the frequency domain by a spectral measurement unit, which looks for the presence of energy in a prescribed portion of the frequency spectrum of the amplifier output

5 signal, to determine whether the frequency spectrum of the
output signal has departed from that of the frequency
spectrum of the input signal. The amount of energy
transferred through a band pass filter during this swept
spectral measurement is used as an indicator of spectral
distortion, rather than the desired signal, and is
therefore representative of error. The error measurement is
then coupled to the weighting coefficient generator, which
is operative adjust the weighting coefficients, in such a
manner as to minimize the measured error. The RF input
signal to the auxiliary amplifier A_2 includes both a
predistorted version of the desired RF input component, as
well as a predistorted version of the complementary phase
IMD component extracted by the RF carrier cancellation
combiner 230.

10 Since the RF signal to the auxiliary RF amplifier A_2
contains a phase-inverted version of the IMD component (as
extracted by the carrier cancellation combiner 230), the RF
output signal produced by RF amplifier A_2 will include the
desired modulated RF carrier, an unwanted IMD component
associated with the desired carrier, plus an amplified
version of the phase-inverted IMD component that is aligned
with and has a larger amplitude than the unwanted IMD
produced by the main RF amplifier A_1 .

20 These two RF amplifier output signals are combined in
the quadrature hybrid 140 to produce a composite signal at
output port 143. As described above, this composite signal
contains both a constructive summation of the desired
amplified modulated RF carrier components produced by each
amplifier to the intended amplification level, and a
cancellation of unwanted IMD components. Phase alignment of
the RF output signals produced by the RF amplifiers A_1 and
 A_2 is readily achieved by minimizing carrier power at the
termination port 144 of the quadrature hybrid 140, or by
minimizing distortion energy detected at the output 143.

35 As in the case of the RF power amplifier linearization
mechanism described in the '536 application, the combined
5

5 feed-forward and predistortion approach of the present invention does not suffer from bandwidth or instability issues, associated with feedback linearization systems, thereby providing improved performance and wider bandwidth correction at lower cost.

10 While we have shown and described an embodiment in accordance with the present invention, it is to be understood that the same is not limited thereto but is susceptible to numerous changes and modifications as are known to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein, but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.

WHAT IS CLAIMED

1 1. An RF power amplifier arrangement comprising:
2 an RF input port to which an RF input signal is
3 applied;
4 an RF output port from which an RF output signal is
5 derived;
6 first and second RF signal processing paths coupled
7 between said input and output ports and containing first
8 and second RF power amplifiers;
9 said first RF signal processing path including a first
10 RF signal vector modulator, that is controllably operative
11 to adjust one or more parameters of a first RF input signal
12 component applied to said first RF power amplifier;
13 said second RF signal processing path including a
14 second RF signal vector modulator, that is controllably
15 operative to predistort the input signal component applied
16 to said second RF power amplifier, and an intermodulation
17 distortion (IMD) extraction circuit coupled to an output of
18 said first RF power amplifier, and being operative to
19 generate said second RF input signal component as a
20 combination of said RF input signal and an IMD component
21 present in an amplified RF output signal from said first RF
22 power amplifier; and
23 an output signal combiner coupled to outputs of said
24 first and second RF power amplifiers and said output port,
25 and being operative to produce said RF output signal as a
26 composite RF output signal, in which RF carrier components
27 produced by said first and second RF power amplifiers
28 constructively sum and IMD components produced thereby
29 destructively combine.

1 2. An RF power amplifier arrangement according to
2 claim 1, wherein said first and second RF power amplifiers
3 are matched RF power amplifiers.

1 3. An RF power amplifier arrangement according to
2 claim 1, wherein said second RF signal vector modulator is
3 controllably operative to predistort a second RF input
4 signal component applied to said second RF power amplifier.

1 4. An RF power amplifier arrangement according to
2 claim 1, wherein said IMD extraction circuit includes a
3 cancellation combiner that is operative to differentially
4 combine a sample of the amplified RF output signal produced
5 by said first RF power amplifier with a portion of said RF
6 input signal applied to said second signal processing path
7 to derive said IMD component, and to combine said IMD
8 component with said portion of said RF input signal applied
9 to said second signal processing path, so as to derive said
10 second RF input signal component as a combination of said
11 RF input signal and said IMD component where said IMD
12 component is phase-inverted with respect to the carriers
13 when compared to the output of the first RF power
14 amplifier.

1 5. An RF power amplifier arrangement according to
2 claim 4, further including a controller which is operative
3 to control said second vector modulator in accordance with
4 intermodulation distortion energy measured at the output of
5 said output signal combiner.

1 6. An RF power amplifier arrangement according to
2 claim 2, further including a controller which is operative
3 to control said first and second controlled RF signal
4 vector modulators in accordance with a measure of
5 intermodulation distortion energy produced in at least one
6 of said first and second RF power amplifiers.

1 7. An RF power amplifier arrangement according to
2 claim 6, further including an IMD distortion detector
3 coupled to said output port and being operative to couple
4 a measure of IMD distortion in said RF output signal to
5 said controller.

1 8. An RF power amplifier arrangement according to
2 claim 2, wherein said amplitude/phase alignment unit
3 coupled in series with said first RF power amplifier is
4 controllably operative to adjust the amplitude and phase of
5 said first RF input signal components applied to said first
6 RF power amplifier, and further including a controlled
7 attenuator installed between said output of said first RF

power amplifier and said IMD extraction circuit, and further including a controller which is operative to control said amplitude/phase alignment unit and said controlled attenuator in accordance with a measure of intermodulation distortion energy produced in at least one of said first and second RF power amplifiers.

9. An RF power amplifier arrangement according to claim 1, wherein said first and second controlled RF signal vector modulators are controllably operative to adjust the phase and amplitude of said first and second RF input signal components applied to said first and second RF power amplifiers, and further including a controller which is operative to control said RF signal predistorter in accordance with a measure of intermodulation distortion energy produced in at least one of said first and second RF power amplifiers.

10. An RF power amplifier arrangement comprising main and parallel RF signal processing paths coupled to an RF signal input port to which a modulated RF carrier signal is applied, said main path including a main path amplitude/phase alignment unit coupled to a main path RF power amplifier, said parallel path including a parallel path predistortion circuit coupled to a parallel path RF power amplifier, said parallel path predistortion circuit being controllably operative to predistort an RF signal component applied to said second RF power amplifier, and an intermodulation distortion extraction circuit coupled to said main and parallel paths and being operative to extract an intermodulation distortion component present in an amplified RF output signal from said first RF power amplifier, and an RF signal processing path combiner that is operative to combine RF outputs of said main and parallel path amplifiers to produce a composite RF output signal in which amplified modulated RF carrier components produced by said main and parallel path RF amplifiers constructively sum and intermodulation distortion components produced thereby destructively combine.

1 11. An RF power amplifier arrangement according to
2 claim 10, wherein said first and second RF power amplifiers
3 are matched RF power amplifiers.

1 12. An RF power amplifier arrangement according to
2 claim 10, wherein said parallel path predistortion circuit
3 is controllably operative to predistort said RF signal
4 component applied to said second RF power amplifier in
5 accordance with different work functions of the
6 instantaneous amplitude of said modulated RF carrier
7 signal.

1 13. An RF power amplifier arrangement according to
2 claim 10, wherein said intermodulation distortion
3 extraction circuit is operative to differentially combine
4 an amplified RF output signal produced by said main path RF
5 power amplifier with a portion of said modulated RF carrier
6 signal to derive said intermodulation distortion component,
7 and wherein said parallel signal processing path is
8 configured to combine said intermodulation distortion
9 component with a portion of said modulated RF carrier
10 signal for application to said parallel path predistortion
11 circuit.

1 14. An RF power amplifier arrangement according to
2 claim 12, further including a controller which is operative
3 to control said main path and parallel path predistortion
4 circuits in accordance with a measure of intermodulation
5 distortion energy produced in at least one of said main and
6 parallel path RF power amplifiers.

1 15. An RF power amplifier arrangement according to
2 claim 13, further including a controller which is operative
3 to control said main path and parallel path predistortion
4 circuits in accordance with said intermodulation distortion
5 component.

1 16. An RF power amplifier arrangement according to
2 claim 15, further including an intermodulation distortion
3 component detector coupled to an output port of said RF
4 signal processing path combiner and being operative to
5 couple a measure of intermodulation distortion to said

6 controller.

1 17. An RF power amplifier arrangement according to
2 claim 15, wherein said main path predistortion circuit is
3 controllably operative to adjust the amplitude and phase of
4 a main path RF carrier signal applied to said main path RF
5 power amplifier, and further including a controlled
6 attenuator installed between said output of said main path
7 RF power amplifier and said intermodulation component
8 extraction circuit, and further including a controller
9 which is operative to control said main path predistortion
10 circuit and said controlled attenuator to minimize the
11 power detected at the output of a carrier cancellation
12 combiner.

1 18. An RF power amplifier arrangement according to
2 claim 13, wherein said main path and parallel path
3 predistortion circuits are controllably operative to adjust
4 the phase and amplitude of main path and parallel path
5 modulated RF carrier signals applied to said main path and
6 parallel path RF power amplifiers, and further including a
7 controller which is operative to control said predistortion
8 circuits in accordance with a measure of intermodulation
9 distortion energy produced in at least one of said main
10 path and parallel path RF power amplifiers.

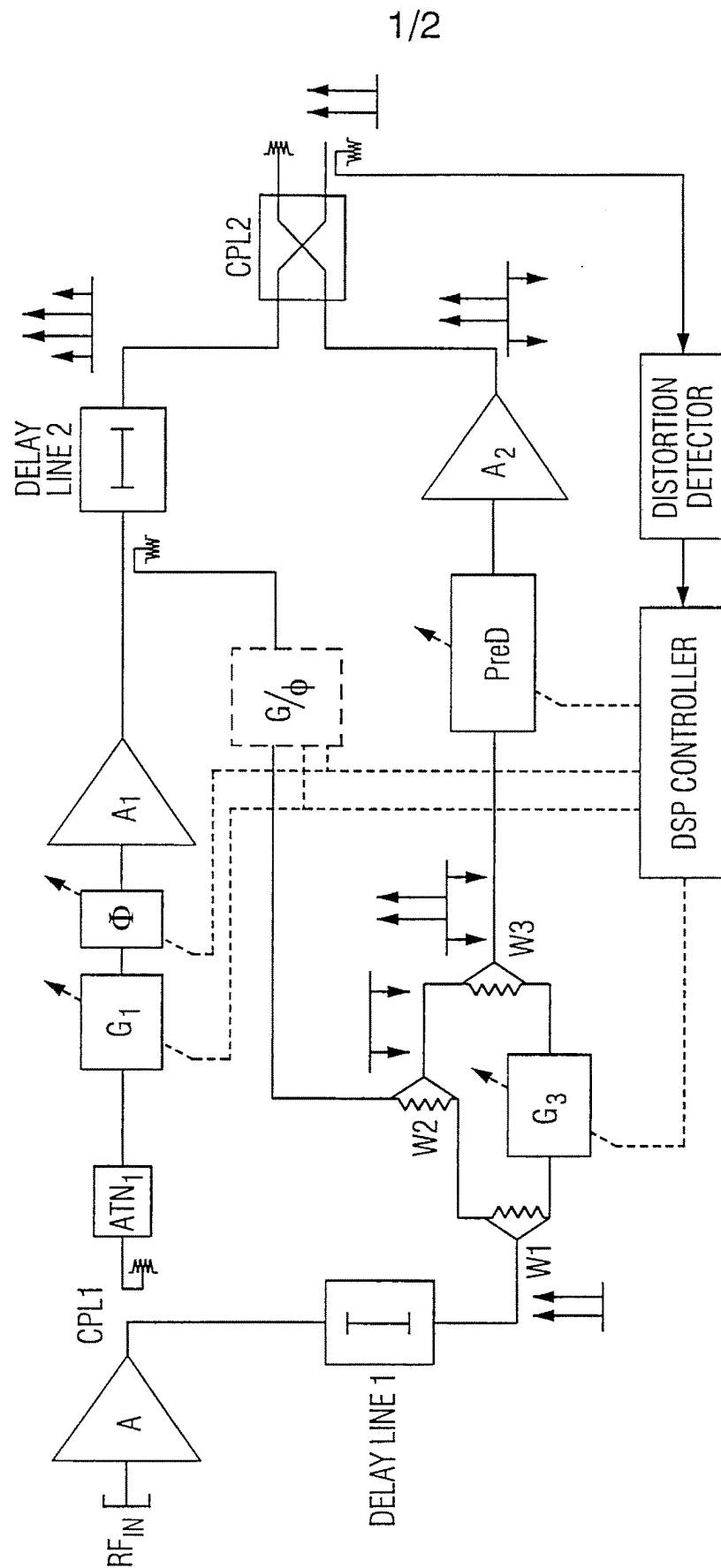


FIG. 1

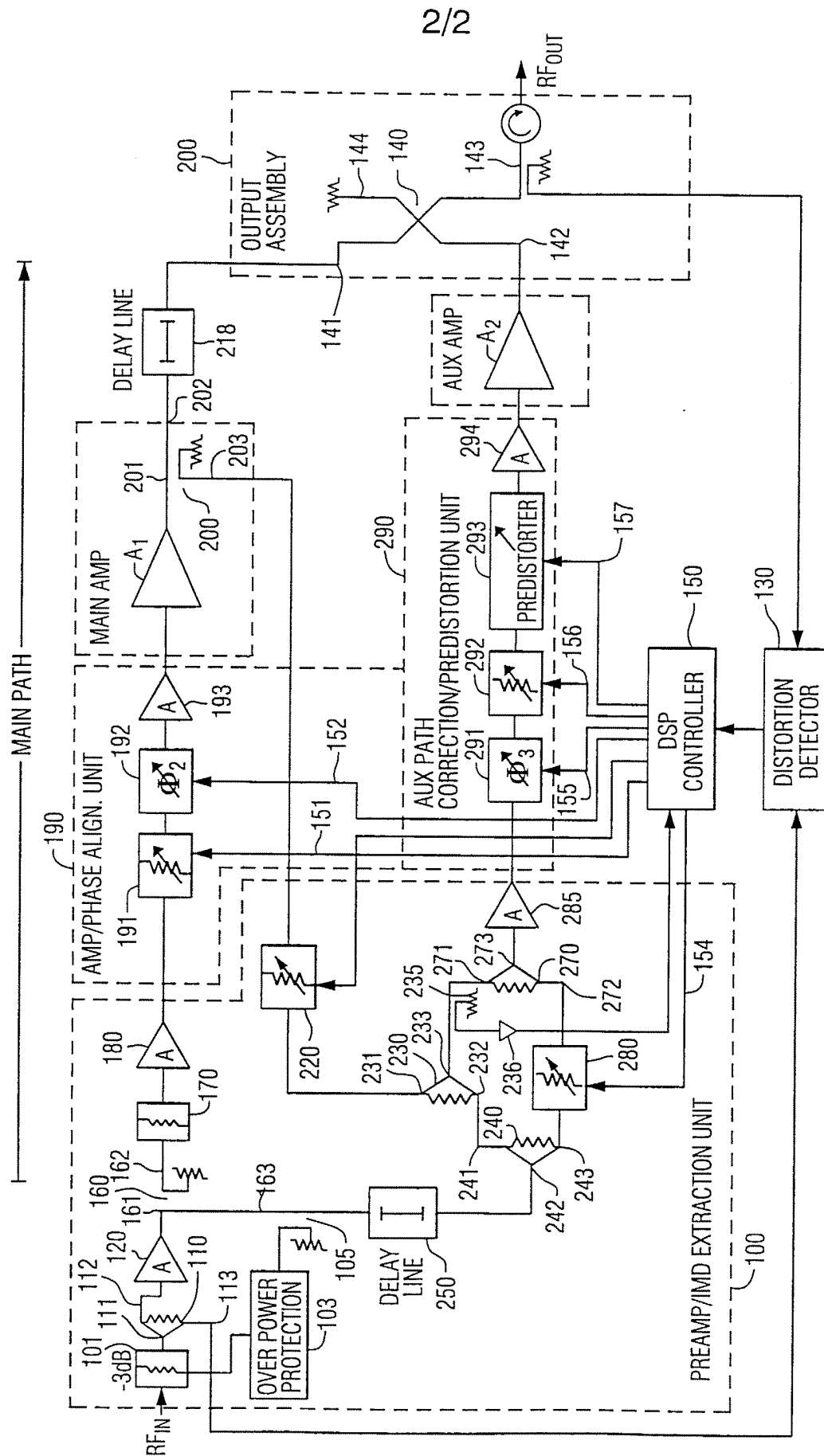


FIG. 2

INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/US00/19365
A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H03F 1/26, 1/00; H04K 1/02

US CL : 330/149, 151; 375/296

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 330/149, 151; 375/296, 297

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST; vector modulatu?, attenuator, phase shifter, predistort?, IMD, control?

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,528,196 A (BASKIN et al) 18 June 1996 (18/06/96), figure 2, cols. 3 and 4.	1-7, 9-16, 18
A	US 5,898,339 A (MARUYAMA et al) 27 April 1999 (27/04/99), Figure 2.	1-18
A	US 5,877,653 A (KIM et al) 02 March 1999 (02/03/99), Figure 2.	1-18

☐

Further documents are listed in the continuation of Box C.

☐

See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier document published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search

14 SEPTEMBER 2000

Date of mailing of the international search report

02 OCT 2000

 Name and mailing address of the ISA/US
 Commissioner of Patents and Trademarks
 Box PCT
 Washington, D.C. 20231

Facsimile No. (703) 305-3230

Authorized officer

PATRICIA THUY NGUYEN

Telephone No. (703) 308-1927